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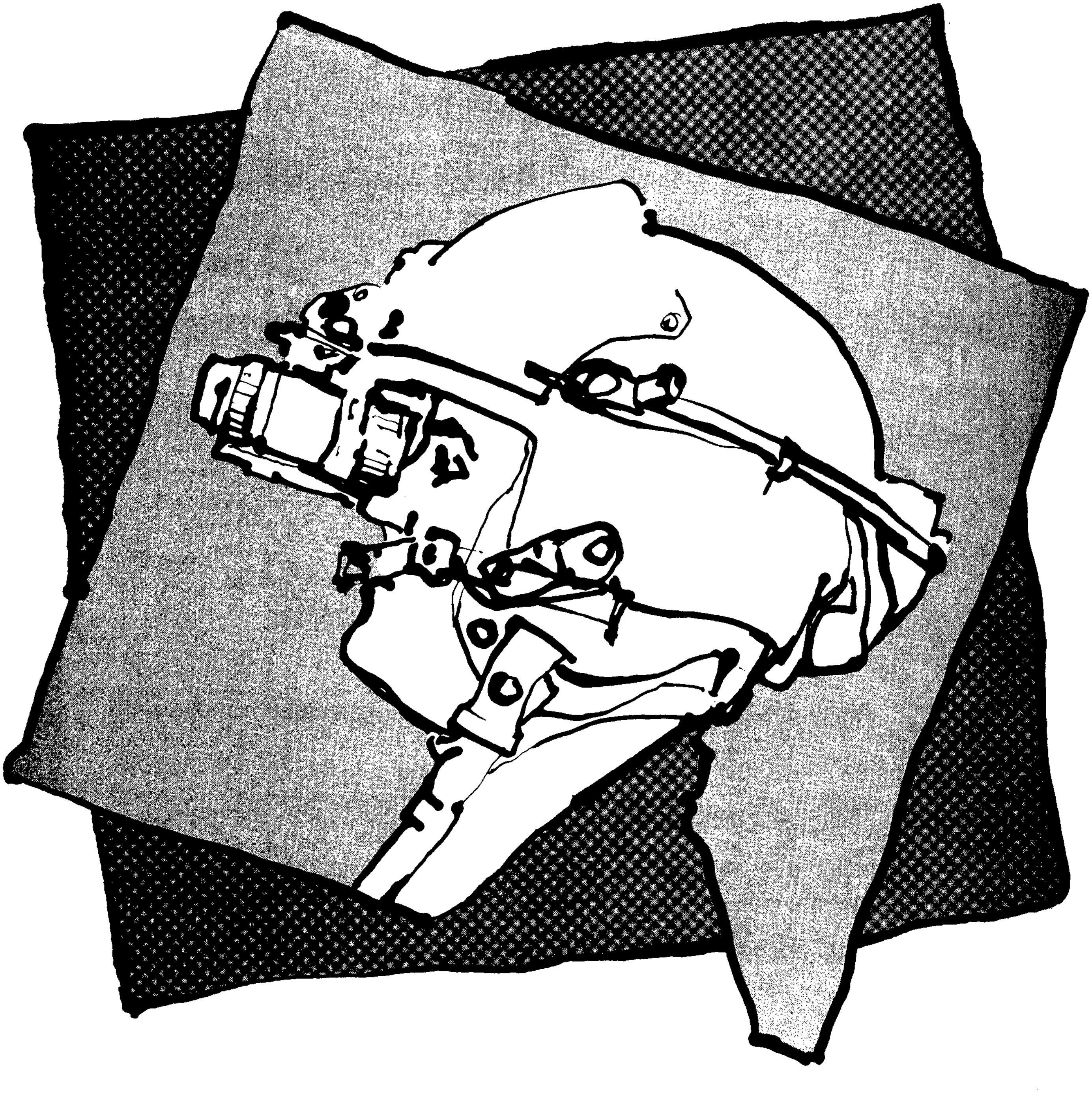

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Reports of Sensory Illusions and Other Adverse Effects

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Human Factors of Night Vision Device Use In Southwest Asia: Reports of Sensory Illusions and Other Adverse Effects

By
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January 1992

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To identify the variety of sensory illusions experienced by aircrews flying with night vision devices (NVDs) in Southwest Asia, an open-ended questionnaire was distributed to Army aviation units while deployed in the fall of 1990 and upon return to home station in the spring of 1991. Eighty-seven questionnaires were returned. In 85 of the incidents reported, aviators were using the AN/AVS-6 Aviator's Night Vision Imaging System (ANVIS). Two AH-64 pilots were using a thermal imaging system (FLIR). Most of the sensory events were experienced during good weather, over open desert terrain, during low levels of ambient illumination. Events occurred during all phases of flight but most frequently in cruise, low level, and during approach/landing. Degraded visual cues accounted for more than half of all reports, with loss of visual horizon and degraded resolution most frequently mentioned. Other common illusions were misjudgments of height above open desert terrain, undetected aircraft drift, and errors in judging closure rates. These first-hand reports can be used to better prepare aviators to fly at night, in a desert environment, and reduce safety risks.

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INTRODUCTION

The use of night vision devices (NVDs) to fly at night was a key component in conducting Army aviation operations in Southwest Asia. Although these electro-optical devices greatly enhance night vision, perceptual cues are impaired. Compared to flying under day visual flight rules (VFR) conditions, aviators using NVDs have limited visual acuity, field-of-view, color vision and depth perception [1,5,6]. Additional problems may include binocular rivalry, visual fatigue, increased stress, and workload.

The two types of NVDs used in Southwest Asia were image intensification (I^2) systems and thermal-imaging systems. I^2 systems amplify low-intensity ambient illumination to produce a bright image of the scene [1,5,10]. These include the AN/PVS-5 night vision goggle (NVG) which uses second generation I^2 tubes and the AN/AVS-6 aviator's night vision imaging system (ANVIS) which uses lightweight high-performance third-generation tubes. Thermal systems, on the other hand, sense and display infrared (IR) radiation emitted by objects in the scene [1,5,7]. The forward-looking infrared (FLIR) sensor of the pilot night vision system (PNVS) on the AH-64 Apache helicopter is a thermal-imaging system. The limitations of NVDs, which may contribute to perceptual problems, have been described in previous studies [1,6,7,10].

Vision is the most important sense used by aviators to maintain spatial orientation [4]. In Southwest Asia, the featureless terrain, sand dunes, and continuous airborne sand significantly degrade visual perception. Degraded visual cues associated with NVD use, combined with adverse environmental conditions and stressful flight profiles, increase the probability of visual illusion and errors [8,11].

Degraded visual cues were identified as a major contributing factor in U.S. Army NVG aircraft accidents in Southwest Asia [9]. Little is known, however, about the specific visual phenomena associated with NVD use in this unique environment. To learn more about these visual phenomena, individual reports were requested from aircrewmembers who experienced adverse visual effects or illusions while flying in this environment and using NVDs.

METHODS AND MATERIALS

Copies of the questionnaire at appendix A were distributed to aviation units while deployed to Southwest Asia during October and November 1990. Additional questionnaires were mailed to aviation units after their return to home station in the spring of 1991. Aircrewmembers were encouraged to report any episodes of disorientation, sensory problems, or illusions noted while flying with NVDs. Respondents were requested to use a separate questionnaire for each occurrence reported. The form included questions about NVD hardware, flight parameters, environmental conditions, and demographic data. To ensure anonymity, unit and individual names were not requested. Data were analyzed using a common epidemiological format [3].

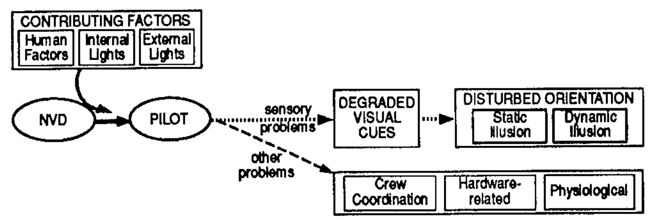

Figure 1. The NVD-pilot model. (Reproduced from USAARL Report 91-15 [2])

This study design was based on a previous report concerning visual illusions experienced by aviators flying with NVDs [2]. A model (figure 1) from the previous report was used to organize the variety of subjective accounts. The basis of the model is the "NVD-pilot interface" which may be influenced by various "contributing factors." This study describes only the sensory problems which may result and classifies these as either a simple report of "degraded visual cues" or a more complex visual perception problem termed "disturbed orientation." A further division into "static illusions" and "dynamic illusions" is made, based on whether motion (real or perceived) was an essential element.

RESULTS

Eighty-seven questionnaires, completed by 58 aircrewmembers, were returned to the Army Safety Center. All reported using the AN/AVS-6 aviator's night vision imaging system (with the exception of two AH-64 pilots) in a variety of

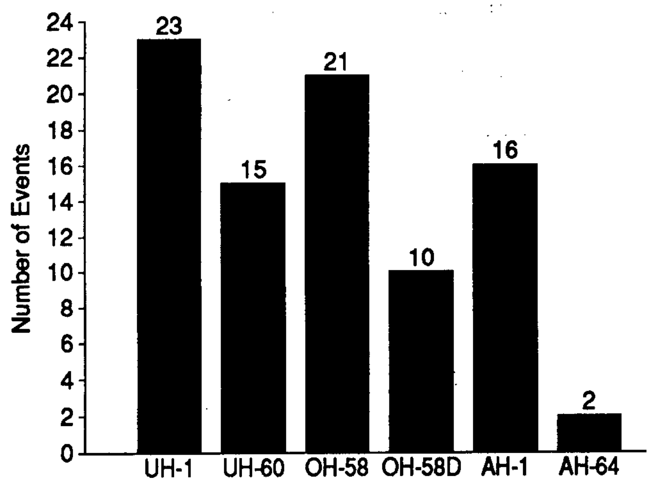

Figure 2. Aircraft type associated with event (N=87)

aircraft (figure 2). At the time of the event, mean respondent age was 32.5 years (S.D.=6.6), with 77.6 percent flying as pilot, 12.1 percent as copilot, and 10.3 percent as instructor pilot. Total flight experience ranged from 220 hours to more than 8,000 hours, with a median of 1,500 flight hours. Total flight time in Southwest Asia and NVD flight hours are plotted in figure 3.

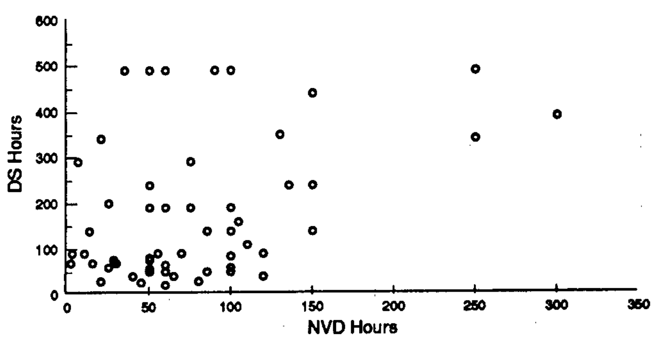

Figure 3. Total NVD flight hours and Southwest Asia experience for aviators at time of event (N=87)

Most of the perceptual problems occurred during good weather, over open desert terrain, during low levels of ambient illumination (table 1). A wide range of flight conditions were reported at the time of the event, the most common being airspeeds greater than 70 knots and altitudes above 150 feet agl (table 2). Events were reported during all phases of flight, but most frequently in cruise (above 150 feet agl), low level

Table 1. Environmental conditions at time of event

	Total respondents (N=87)	
Conditions	Percent	(N)
Ambient weather		
Clear	54	(47)
Blowing sand	29	(25)
Fog/haze	9	(8)
Poor visibility	8	(7)
Terrain		
Open desert	97	(84)
Sparse vegetation	38	(33)
Dry lake bed	2	(2)
Illumination level		
0-20 percent	33	(29)
21-40 percent	10	(9)
41-80 percent	16	(14)
81-100 percent	24	(21)
Any	16	(14)

Note: Illumination level is approximated by the percent of the moon surface that is illuminated (e.g., new moon=zero percent illumination, full moon=100 percent illumination, etc.)[5]. This and subsequent tables reflect the number of responses to each question, therefore, column totals may not equal respondent total.

Table 2. Flight conditions at time of event

	Total respondents (N=87)	
Conditions	Percent	(N)
Airspeed range (knots)		
0-20	24	(21)
21-40	7	(6)
41-70	8	(7)
71-100	28	(24)
101-150	8	(7)
Multiple	25	(22)
Altitude range (feet agl)		
0-25	13	(11)
26-50	13	(11)
51-100	7	(6)
101-150	18	(16)
151-300	20	(17)
>300	5	(4)
Multiple	25	(22)

Table 3. Phase of flight at time of event

Flight phase	Total respondents (N=87) Percent	(N)
Cruise	28	(24)
Approach/landing	26	(23)
Low level	21	(18)
All phases	13	(11)
Contour	10	(9)
Takeoff/climb	8	(7)
Hover (OGE)	7	(6)
Formation flight	7	(6)
Bank	3	(3)
Hover (IGE)	1	(1)
Nap-of-the-earth	1	(1)

(100 to 150 feet agl), and during approach/landing (table 3).

Degraded visual cues accounted for 53.9 percent of all reports, with impaired visual acuity the most common presentation. Loss of visual horizon and degraded resolution were most frequently mentioned (table 4). The most common static illusion was difficulty in judging height above open desert terrain, while undetected aircraft drift and error in judging closure rates were the most frequently reported dynamic effects (table 4). Spatial disorientation and illusions of aircraft movement were also reported. Representative quotations from aircrewmember reports are organized according to the model and included in appendix B.

Table 4. Reports of sensory problems

Report	Total respondents (N=87) Percent	(N)
Degraded visual cues		
Loss of visual horizon	26	(23)
Degraded resolution/ insufficient detail	13	(11)
Impaired depth perception	7	(6)
Brownout	7	(6)
Degraded acuity due to shadows	1	(1)
Static illusions		
Faulty height judgment	14	(12)
False horizon	3	(3)
Faulty attitude judgment	1	(1)
Dynamic illusions		
Undetected aircraft drift	8	(7)
Faulty closure judgment	6	(5)
Disorientation (vertigo)	5	(4)
Illusory attitude perception	2	(2)
Illusory altitude change	1	(1)
Illusory forward flight	1	(1)
No sensation of movement	1	(1)
Pitch-up illusion	1	(1)
Illusory fog layer	1	(1)
The leans	1	(1)

Aviators incorporated a variety of cockpit activities and flying techniques in response to the events (table 5). More than two-thirds of the aviators reporting relied on instrument flight and close monitoring of the radar altimeter. Increasing visual scan and landing to a complete

Table 5. Outcome of events

Outcome	Total respondents (N=87) Percent	(N)
Cockpit activities		
Cross-check/fly instruments	44	(38)
Monitor radar altimeter	22	(19)
Increase crew coordination	17	(15)
Copilot cross-check instruments	8	(7)
Transfer aircraft controls	7	(6)
Monitor barometric altimeter	2	(2)
Use pink filter	1	(1)
Monitor map	1	(1)
Adjustment to flying technique		
Land to a complete stop	10	(9)
Increase scan	9	(8)
Decrease altitude/descend	9	(8)
Decrease airspeed	8	(7)
Increase altitude	5	(4)
Corrective action to avoid mishap	5	(4)
Fly msl altitude	1	(1)
Slow vertical scan	1	(1)
Avoid looking high on horizon	1	(1)
Perform ITO/landings	1	(1)
Adverse mission outcomes		
Performed go-around	10	(9)
Aborted mission	9	(8)
Increased fatigue/anxiety	7	(6)
Ground impact/hard landing	6	(5)
Eyestrain/visual fatigue	1	(1)
Engine overtorque	1	(1)

stop to avoid blowing sand were the most frequently reported changes in technique.

There were 30 reports of a negative outcome associated with the NVD event. These ranged from fatigue or aborting the mission to ground impacts or hard landings, including a Class A (aircraft destroyed) OH-58D accident. Further analysis of these events (table 6) indicate they primarily occurred in the open desert, with very low illumination levels, while making an approach or landing in a variety of weather conditions.

Aircrewmembers described several strategies to avoid recurrence of the sensory illusions (table 7). Individual awareness of possible illusions and avoiding areas without visual cues were most frequently mentioned when preparing for missions. Relying more on flight instruments, improving scanning techniques, and better crew coordination were the most frequently described in-flight strategies.

Table 6. Conditions for events with adverse mission outcomes

Conditions	Event (N=30) Percent	(N)
Ambient weather		
Clear	40	(12)
Blowing sand	30	(9)
Fog/haze	20	(6)
Poor visibility	10	(3)
Terrain		
Open desert	87	(26)
Sparse vegetation	20	(6)
Dry lake bed	3	(1)
Illumination level		
0-20 percent	50	(15)
21-40 percent	7	(2)
41-80 percent	13	(4)
81-100 percent	17	(5)
Any	13	(4)
Flight phase		
Approach/landing	40	(12)
Cruise	26	(8)
Contour	10	(3)
Takeoff/climb	10	(3)
All phases	10	(3)
Low level	7	(2)

Table 7. Lessons learned

Techniques	Total respondents (N=87) Percent	(N)
Preflight/planning		
Avoid landing in areas with no visual cues	7	(6)
Increase training/awareness of visual illusions	5	(4)
Avoid dune areas during low illumination	2	(2)
Do not attempt OGE hover	1	(1)
Plan airspeed/altitude based on illumination/visibility	1	(1)
Plan go-around procedures	1	(1)
In-flight		
Use instruments more	13	(11)
Stress better scan techniques	5	(4)
Stress better crew coordination	5	(4)
Require the use of IR filtered light	5	(4)
Require the use of radar altimeter	3	(3)
Adhere to ATM airspeeds/ altitudes	3	(3)
Use echelon approaches for formation flights	2	(2)
Use extreme caution	1	(1)

DISCUSSION

This study identifies safety hazards that should be considered by aviators when planning operations in a desert environment. However, the risk of occurrence, or incidence rates, cannot be determined since there are no denominator data. Only those aircrewmembers who experienced an event were asked to complete the questionnaire. The use of an open-ended questionnaire also inhibits reliable incidence rates, but permits a wide variety of responses.

Reduced visual references created the majority of illusions reported by aviators. Key contributing factors included exposure to sand dune terrain with sparse to nonexistent vegetation and terrain features, combined with degraded acuity during periods of low illumination.

Contour flight was found to be the most unforgiving profile due to the presence of obstacles (sand dunes) and an absence of visual cues. Pilots reported a tendency to inadvertently descend to acquire visual cues.

In the absence of adequate visual orientation cues, the vestibular system and other orienting senses perceive motion and position, often resulting in orientational illusions [4]. Of particular interest is the reported illusion of pitching up after take-off, in the absence of a distinct external visual horizon. This was described by a UH-1 pilot as "the sensation of someone pulling backwards on my seat and [I] thought I was falling backwards." Although commonly reported in high-performance aircraft, this illusion has rarely been reported in rotary wing aircraft. Failure to monitor instruments and, if necessary, transfer controls as did the UH-1 pilot, results in the pilot lowering the nose of the aircraft to cancel the unwanted sensation. This is followed shortly thereafter by ground impact in a nose-low attitude.

Although poor visual orientation was quickly identified as a risk factor when flying in Southwest Asia, these anecdotes describe specific sensory illusions caused by aided flight in a desert environment. Several measures such as the use of radar altimeters, improved scanning techniques, improved crew coordination, and recommended airspeed and altitude limitations have already been incorporated to help reduce the incidence of sensory effects. However, familiarity with sensory illusions that may affect safe NVD flight is critical. These findings can be used to better prepare aviators to fly at night in a desert environment, thereby reducing safety risks.

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Appendix A

Sensory Illusions and Night Vision Devices - Operation Desert Shield

The Army Safety Center would like your input for a report on the human factors and aeromedical aspects of night vision devices (NVDs). During Operation Desert Shield, if you have experienced disorientation or a sensory effect or illusion such as excessive drift, false motion, or loss of horizon while flying NVDs, we'd like to hear about it. Please provide as much information as you can, using a separate copy of the questionnaire for each illusion.

Type of NVD being used

NVG:
- (1)PVS-5______
- (2)ANVIS______
- (3)Other(describe)______

Infrared:
- (4)Helmet-mounted display______
- (5)Head-down display______
- (6)Fixed head-up display______
- (7)Other (describe)______

Type of aircraft______

Crew position (P/CP/CE/AO, etc.)______

Description of event

Terrain:
- (1)Open desert______
- (2)Sparse vegetation______
- (3)Moderate vegetation/trees______
- (4)Mountains______
- (5)Water______
- (6)Other (describe)______

Weather:
- (1)Clear______
- (2)Rain______
- (3)Blowing sand______
- (4)Poor visibility______
- (5)Other (describe)______

Time (24-hour clock):______

Altitude (agl/msl):______

Airspeed:______

% Illumination:______ (or moon phase)______

Description of incident:

______
______
______
______
______

How often does this happen?______

What was the outcome of the event? What happened? What did you do to stop it?

______
______

Personal data (at time of event):

Age______
Total flying hours______
NVD hours______
Total Desert Shield flying hours______

Aviator Excerpts

The following excerpts taken from the questionnaires are organized according to the model categories (figure 1). The selections have been altered only to correct punctuation or grammar. Any suggestions or remedies are the opinion of the respondents and are not endorsed by the author.

I. Reports of degraded visual cues

A. *Loss of visual horizon*

"At low levels of illumination [there is] no visual horizon. You have to rely on crew coordination, inside cross-check, and fly an msl altitude with cross reference of the radar altimeter."

"There were a lot of sand particles in the air and visibility was poor. It was next to impossible to make out the horizon."

"During cross-country flying in very low illumination levels, with altitude greater than 100 feet [agl], loss of definable horizon is a continuous occurrence."

B. *Degraded resolution/insufficient detail*

"While moving slowly up the back side of a sand dune, we lost sight of the top of the sand dune we were overflying. Upon closer observation, we noted it had blended into the sand dune in front of it."

"While hovering over dunes with vegetation, it is almost impossible to detect dunes without vegetation."

"Lost ground reference due to zero percent illumination and lack of ground contrast."

C. *Impaired depth perception*

"In an out-of-ground-effect hover or low airspeed in conjunction with sand approaches, visual cues to depth perception and motion are severely restricted."

"Terrain appears to flatten out; i.e., small hills, ridges appear to disappear and become level ground."

"While landing to a FARP, blowing sand obscured vision, causing a degradation of depth perception. Everything appeared to be 5 to 10 feet farther than it actually was."

D. *Brownout*

"During approach to parking, dust envelopment caused a total loss of reference, except for a chem stick. Excessive drift was noticed by the second crewmember, and a go-around was initiated."

"During takeoff, copilot lost reference to outside references due to blowing sand. He announced 'descending' at which time I [pilot] verified altitude at 40 feet agl and proceeded to take the controls and contacted ground."

"Approaches at or below etl resulted in the dust cloud moving forward of the cockpit environment, therefore obstructing vision."

E. *Degraded acuity due to shadows*

"Medium-level clouds with bright illumination, causing shadows on the desert, gave false cues as to the terrain underneath."

II. Reports of static illusions

A. *Faulty height judgment*

"During landings, the last 3 feet it is difficult to judge height, as well as en route flight."

"Unable to perceive height above the desert from 100 to 500 feet agl."

"While flying over open desert or sparsely vegetated areas without radar altimeters, under NVGs, it's extremely difficult to determine your height during flight and on approaches."

B. *False horizon*

"While flying across the open desert, I experienced a false-horizon illusion, which was caused by the different colored sand as well as clouds."

C. *Faulty attitude judgment*

"...each time I [PC] announced a command to turn, he [CP] would rely on outside references to establish the correct attitude of the aircraft in relation to a horizon that could not be seen. It took only a very short time for our aircraft to be in a poor but not yet dangerous profile of flight..."

III. Reports of dynamic illusions

A. *Undetected aircraft drift*

"In an out-of-ground-effect hover...drift is not detected until well developed...."

"Difficulty maintaining position over a point on the ground, [resulting in] right-rear drift."

"Extra drift on takeoff as we were enveloped by sand."

B. *Faulty closure judgment*

"...with poor illumination and little if any ground references, it is extremely tough to judge your rate-of-closure as you approach your intended touchdown point."

"...when making approaches to featureless terrain, the nose-low attitude will give the pilot a feeling that the approach is being made too fast, and too fast of a descent."

"While attempting to land, PC could not judge rate of closure."

C. *Disorientation (vertigo)*

"...throughout initial portion of the flight, PC and CE experienced spatial disorientation, [and] IP was on the controls. He was inside the aircraft flying instruments...with the PC calling airspeed and altitude...."

"...I [IP] started a left 180-degree turn. While turning, I caught a glimpse of the true horizon on the TIS [OH-58D]. Looking up, I had no visual references...but I happened to see the moon coming out from behind the clouds...I was temporarily spatially disoriented and transferred the controls to my SIP in the right seat."

D. *Illusory attitude perception*

"While transitioning from the left rear to the right rear of the lead aircraft, I experienced an extreme right rolling motion and felt that I was rapidly approaching a 90-degree right-bank angle."

"[Flying] chalk 2 in a flight of 2... although instruments indicated level flight, it appeared chalk 1 was nose diving into the ground, although he wasn't...."

E. *Illusory fog layer*

"Moonlight passing through scattered to broken layer [of clouds] appears as though flight is above scattered fog."

F. *Illusory altitude change*

"[Fully loaded AH-1]...causing a nose-low attitude of 5 degrees greater than normal unloaded flying attitude, the aircraft feels as if it is constantly descending."

G. *Illusory forward flight*

"...on takeoff, as we were enveloped by sand, it seemed we were moving forward, but airspeed was zero. We were actually in a vertical climb."

H. *No sensation of movement*

"Flying to our objective at 150 feet agl under NVGs, my sensation was as if I were floating in air with no forward speed."

I. *Pitch-up illusion*

"Sitting in the left seat [UH-1] after take-off, [I] looked to my left for possible traffic and judge what I could see. After turning back to the front, I got the sensation of someone pulling backwards on my seat and [I] thought I was falling backwards."